Water

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GROUNDWATER RESOURCES EVALUATION

MURRAY RIVER

THE CANADA - PRINCE EDWARD ISLAND
WATER MANAGEMENT AGREEMENT

Environment Canada Environnement Canada

Prince Edward Island
Department of the Environment

GROUNDWATER RESOURCES EVALUATION

MURRAY RIVER

Groundwater Resources Evaluation - Murray River

Executive Summary

A test drilling program and review of the available hydrogeological data indicate that the natural quantity and quality of groundwater resources throughout most of the community of Murray River are generally good and sufficient to meet the community's needs. Locally there are areas where elevated concentrations of iron and manganese have been the cause of some concern, although these occurrences pose no threat to health. Incidents of groundwater contamination have been comparatively rare in Murray River, although the nature of the overburden materials in the area make the underlying aquifer relatively vulnerable to contamination.

The test drilling program conducted under this project, as well as a review of the available well data indicate that good potential exists for the development of high capacity wells in the area. Yield testing of the two test wells indicates a combined capacity of some 1,100 m^3/ day, far in excess of the community's expected water needs. The test site, situated in the south east portion of the community is generally suitable for the implementation of some form of well field protective measures, and hydrogeological data derived from the pump testing has been used to calculate the probable extent of these protective zones.

While the water needs of the community are generally adequately met by existing on-site wells, the community should take steps to identify areas for future water supply development against the time when these resources may be needed, and consider implementing some form of groundwater protection measures, to ensure the future integrity of groundwater resources in these areas. It is suggested that the test drilling site identified above would be a good candidate for such an initiative.

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Groundwater Resources Evaluation
Murray River

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1. Introduction

This report documents the findings of a study of the groundwater resources of the Community of Murray River, conducted as part of the Groundwater Resources Evaluation Project, under the Canada - P.E.I. Water Management Agreement. The purpose of this project is to investigate, through a series of studies, the available groundwater resources on selected communities across the Island and to make recommendations regarding the most appropriate manner of developing and protecting this resource, in light of the physical constraints and expected water needs of each community.

In this study data collected through test drilling , pump testing and field reconnaissance, augmented by existing data on the Community of Murray River are assessed , and conclusions drawn regarding the availability and quality of groundwater resources in the study area, and the most appropriate manner of developing this resource.

2. Geography

2.1 Physical Geography

The Community of Murray River is located near the eastern end of Prince Edward Island, 65 km from Charlottetown. The topography is dominated by the valley through which the Murray River flows. The Murray River itself rises approximately 5 km to the north west and empties downstream approximately 6 km. below the community into Murray Harbour. The river is salty to brackish and subject to tidal influence to a point just upstream of the community where it is dammed at MacLure's Pond.

Topography is gently undulating, with slopes generally towards the Murray River. Slopes are steepest on the south side of the river where the average gradient between the river and the higher ground to the south is about 4.5% . On the north side of the river, average slopes are somewhat less averaging about 2.5% . The highest elevations occur on the south side of the river, along the extension of Route 18 west of Route 4, at 30 m. The community covers an area of 180 ha.

The community covers an area of 180 ha, more or less evenly divided between the north and south side of the river. Generally the land is well drained, except for occasional low lying swampy areas, located primarily along the river. A few swampy or perennially wet areas do further inland at elevations significantly above sea level.

2.2 Cultural Geography

There is little population data for the community aside from the 1986 Census. At that time the population was 476, and it is not expected that the community will grow appreciably in the foreseeable future. The community is typical of many smaller Island centres, with a mixture of service industries, fishing and tourism being the main economic activities in the community.

3. Geology

3.1 Surficial Geology

Overburden in the Murray River area consists of well to poorly sorted sand, gravel and boulders south of the river, and a ground moraine composed of sand phase till and kame terrace deposits north of the river (Prest, 1973). From the stratigraphic logs on the well drillers reports, overburden thickness averages 15.4m. The soil survey report (MacDougall and Veer, 1981) indicates predominantly Culloden series soils, which are coarsely textured and strongly acid, derived from glacio-fluvial material on undulating to rolling topography, with good surface drainage, good to rapid sub-surface permeability, and deep water tables. These soils are accompanied by some Alberry series soils on the higher ground north of the river. The Alberry series soils are coarse and moderately coarsely (less than 8% clay) textured, and strongly acid, also derived from ground moraine, on undulating to rolling topography, with good surface drainage, rapid to moderate subsoil permeability and deep water tables.

3.2 Bedrock Geology

Bedrock consists of Lower Permian sedimentary strata of Megacyclic Sequence IIIA (van de Poll, 1981). These consist of red conglomerate and sandstone, generally becoming coarser with depth, with the basal conglomerate overlying conformably the siltstone of Megacyclic Sequence III. Together with the other three megacyclic sequences identified on Prince Edward Island these strata are believed to be slightly younger stratigraphic equivalents of upper portions of the Pictou Group found elsewhere in the Maritime Provinces.

The environment of deposition of these sedimentary strata is considered to be fluvial in origin , and the stratigraphy is characterized by rapid lateral facies changes, representing recurring fluvial cycles. Well drillers reports indicate predominantly sandstone, with some siltstone and claystone. The lithologic logs of two test holes drilled just east of Murray River as a part of these investigations are shown in Figure 4.

4. Hydrogeology

4.1 Existing Well Data

The P.E.I. Department of the Environment has records for only 22 wells drilled in the community of Murray River since 1971. This relatively low number of well records probably indicates that the age of the majority of wells in the community is greater than 20 years. The average well depth is 26 m with a maximum depth of 38 m and a minimum well depth of 17 m. The average length of casing in these wells is 14 m with a maximum of 33 m and a minimum of 7.3 m. Average well yield as reported on the well drillers records is 0.68 litres per second (L/sec) with a number of wells with yields in the range of 0.38 L/sec and a maximum yield reported as 1.28 L/sec.

To make more meaningful the well yield data from the well drillers reports, the well depth or more precisely the saturated portion of the aquifer penetrated by individual wells must be taken into account. As is common on P.E.I., individual aquifers are often difficult to identify, especially as the flow of water through fractures is probably more significant than primary porosity in determining hydraulic conductivity. (Francis, 1981). For these reasons the entire saturated thickness of sediments penetrated by well can be approximated as a single semi- confined aquifer.

All other factors being equal, a deeper well with a greater depth of open hole below the water table would be expected to yield a greater quantity of water than a shallower well. To evaluate the water yielding characteristics of the aquifer then, it is useful to take into account the saturated thickness (water bearing portion) of each well when considering well yield.

As a measure of aquifer yield then, the yield per metre of saturated thickness penetrated, for each well has been calculated. The average yield per metre of saturated thickness in litres per second per metre (L/sec/m) is 0.085 ranging from a minimum of 0.023 L/sec/m to a maximum of 0.22 L/sec/m.

This would mean that on average a well 30 m deep with a static water level of 12 m would be expected to yield approximately 1.5 L/sec. The test holes drilled under this program had yields/ metre of saturated thickness of 0.094 and 0.215 L/sec/m respectively for test holes MR-1 and MR-2. These rates compare favorably with many other areas of the Island, and are nearly twice as high as observed in some other parts of the province.

Examination of the well data indicates a weak correlation between the calculated yield per metre of saturated thickness and both well depths and static water levels. Figure 1 shows a scatter plot of well depth vs. the yield per metre of saturated thickness for wells in the Murray River area, while Figure 2 compares static water levels vs. the yield per saturated thickness.

Figure 1

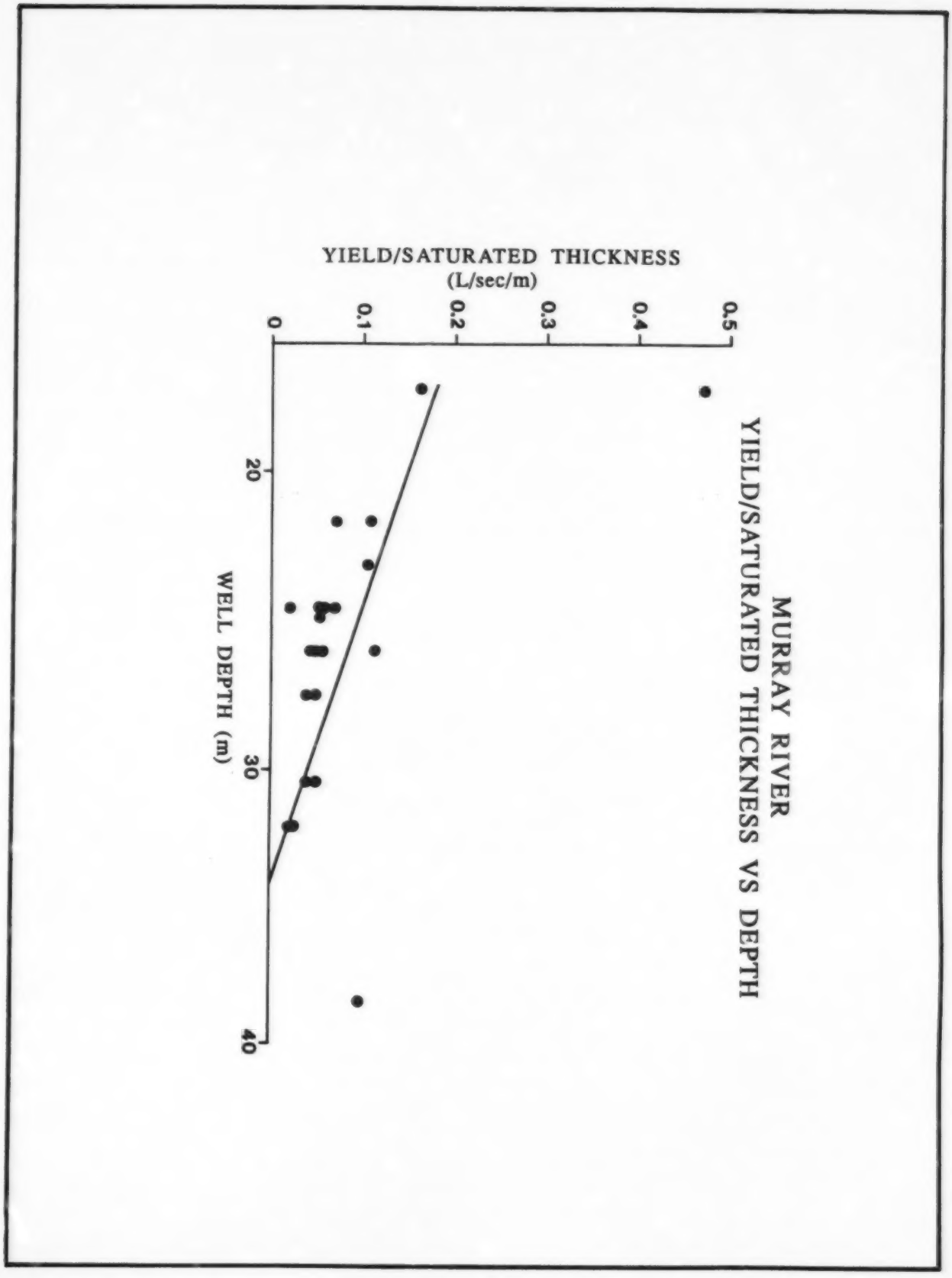
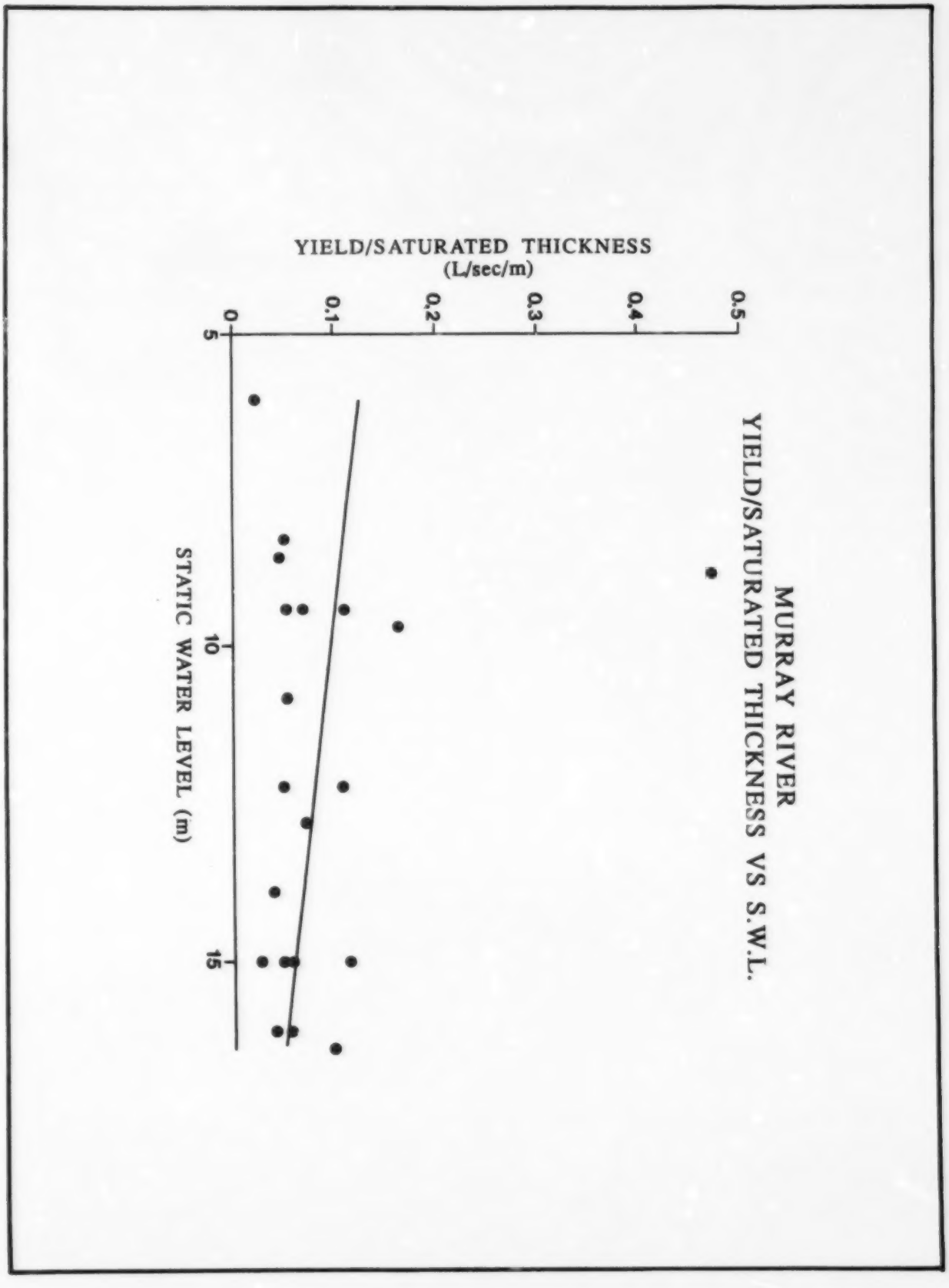

MURRAY RIVER
YIELD/SATURATED THICKNESS VS DEPTH
YIELD/SATURATED THICKNESS
(L/sec/m)
0
0.1
0.2
0.3
0.4
0.5
20
30
40
WELL DEPTH (m)

Figure 2


MURRAY RIVER
YIELD/SATURATED THICKNESS VS S.W.L.
YIELD/SATURATED THICKNESS
(L/sec/m)
0
0.1
0.2
0.3
0.4
0.5
5
10
15
STATIC WATER LEVEL (m)

In each case the graphs suggest that the highest yields per metre of saturated thickness (that is the most productive zones) correlate with the shallower wells, or as in the case of Figure 2, well where the static water levels are relatively shallow (ie. closer to ground level). In both cases the explanation for this feature can be found in the nature of the fracturing in the bedrock aquifer. Typically on P.E.I. fracture frequency and the size of fracture apertures are greatest nearest the ground surface and decline with depth (Francis, 1981). Since it is the fracturing that provide the principle conduit through which groundwater flows, these shallow portions of the aquifer tend to be the most productive. Thus while a deeper well may be capable of a higher yield compared to a shallower well, the gains in yield may not be in proportion to the increase in well depth. Similarly in areas of deep water tables (greater depths to the static water level) much of the highly fractured portion of the bedrock is not saturated and thus not capable of contributing to well yield.

4.2 Test Drilling and Pump Testing

To further evaluate the aquifer characteristics in the area, test drilling was conducted at a site just inside the eastern boundary of the community, on the south side of the river. Two test holes were constructed, one on either side of the road that leads along the river to Kirby's Point, near the Northumberland Arena. Following completion of test drilling, each hole was subjected to a step drawdown pump test, and a constant rate test was subsequently conducted.

4.2.1 Site Selection

Selection of a test drilling site involved three criteria. Of prime importance was the selection of a location where appropriated well field protective measures could be adopted. Secondly, it was desirable that the potential use of the area as a water supply area be compatible with existing or potential land use practices, to minimize the likelihood of future land use conflicts. Finally it was desirable to find a location where reasonable well yields could be expected, and that water quality would be acceptable.

The lack of large areas of undeveloped land and concerns over water quality (particularly high iron and manganese concentrations) made potential sites on the north side of the river unattractive, at least as a first choice for test drilling sites.

The site selected (see Figure 3) is near the eastern boundary of the community on the south side of the river, with a test hole constructed on either side of the road leading east towards Kirb's Point.

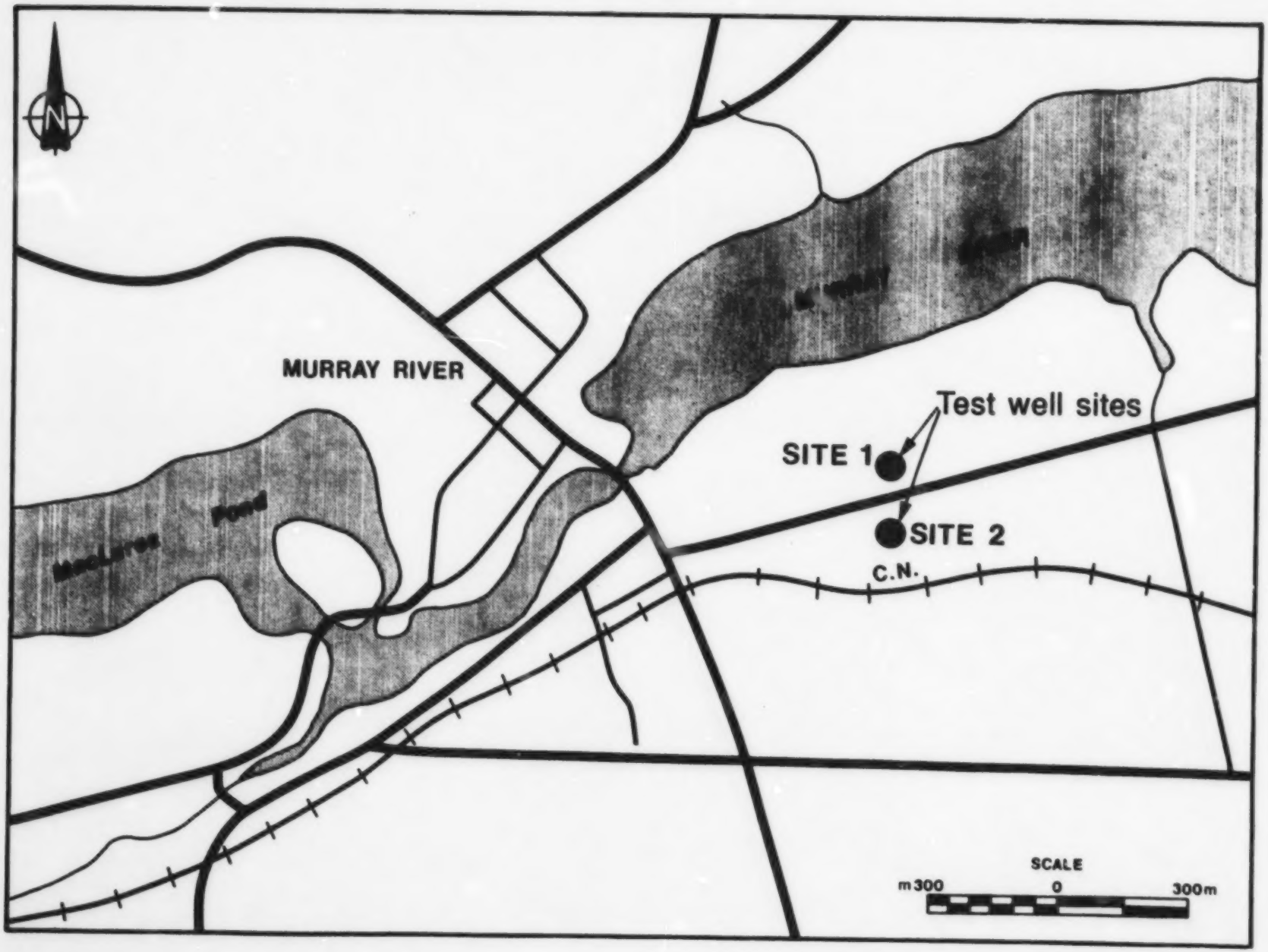

N
MURRAY RIVER
Test well sites
SITE 1
SITE 2
C.N.
SCALE
m300
0
300m

Figure 3

The site is on cleared land which is currently only used for recreational purposes, making the area ideal for the adoption of groundwater protection measures, and with no obvious conflicts between a potential water supply area and other current or expected future activities. In addition, discussions with community officials indicated that an additional supply of water in this area might be of benefit to the arena or to the fire department in this area.

It was expected that well yields would be relatively good anywhere in the Murray River area from the existing data, and thus this factor played a more minor role in the selection of a site. Nonetheless, the locations chosen at the bottom of a small topographic rise was expected to supply a suitable volume of water for the community.

4.2.2 Test Drilling

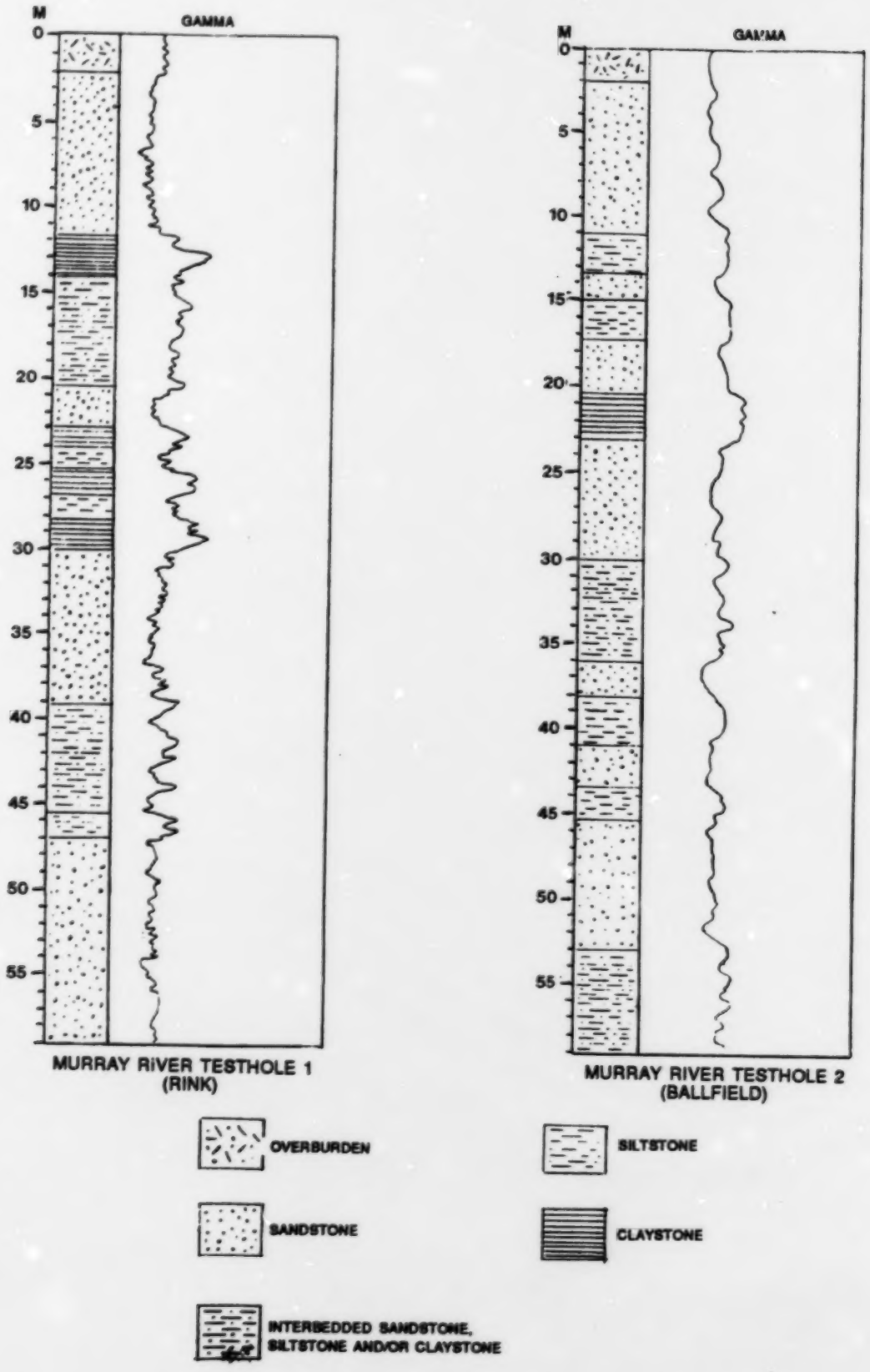
Test hole MR-1 was constructed just to the east of the Northumberland Arena, while test hole MR-2 was constructed directly across the road, approximately 60 m away. The ground elevation at test hole MR-2 is slightly lower (approximately 2-3 m) than at test hole MR-1. Drilling was conducted by a rotary drill rig and samples of drill cuttings were collected for inspection at 3 m intervals.

Each well was initially constructed with a diameter of 15 cm, and with a depth of 60 m. After initial indications of well yield, test hole MR-2 was reamed out to a diameter of 20 cm to facilitate pump testing with a pump of adequate capacity. Both wells are cased to a depth of 12 m and a bentonite seal emplaced in the lower portion of the annular space between the casing and the well bore. Following completion of pump testing, each well was logged by a gamma tool to provide additional information on lithology. Figure 4 presents lithological and gamma logs of both test holes.

4.2.3 Pump Testing

Immediately following completion of each well, a short blow test was conducted to gain a preliminary indication of well yield. Subsequently each well was subjected to a step drawdown test consisting of successive 30 minute steps at different pumping rates. After the stepdrawdown tests were completed a 48 hour constant rate test was conducted, with test well MR-2 near the ball field being pumped at a rate of 9.8 L/sec, with drawdown being recorded both in the pumping well and in test hole MR-1 (used as an observation well). Following completion of the testing, recovery measurements were made in the pumping well, with a few periodic measurements being made in the observation well also.

Figure 4


M
GAMMA
0
5
10
15
20
25
30
35
40
45
50
55
MURRAY RIVER TESTHOLE 1
(RINK)
MURRAY RIVER TESTHOLE 2
(BALLFIELD)
OVERBURDEN
SANDSTONE
INTERBEDDED SANDSTONE,
SILTSTONE AND/OR CLAYSTONE
SILTSTONE
CLAYSTONE

Step drawdown tests:

Test well MR-2 near the ball field, was subjected to a step drawdown test using a line shaft turbine, set at a depth of 45 m. The discharge rate was measured by an orfice wier, and water levels were measured with an electric water level probe in a drop line. The test consisted of 4, 30 minute steps at pumping rates of 5.7, 10.5, 11.4 1nd 12.3 L/sec.

Pumping rates, water levels, drawdowns and specific capacities for the first three steps are shown in Table 1. Specific capacity is a measure of the well yield per unit drawdown in the well over a given time period (in this case 30 minutes). Pumping during the fourth step at a rate of 12.3 L/sec could not be sustained beyond 6 or 7 minutes, at which time the water level was nearing the level of the pump bowls.

The results of the step drawdown test indicate that specific capacity decreases with increasing pumping rates, particularly beyond a pumping rate of 10.5 L/sec. This phenomena, which is commonly noted on the Island is probably related to an increasing head loss due to a greater amount of turbulence in and around the well bore at higher water velocities.

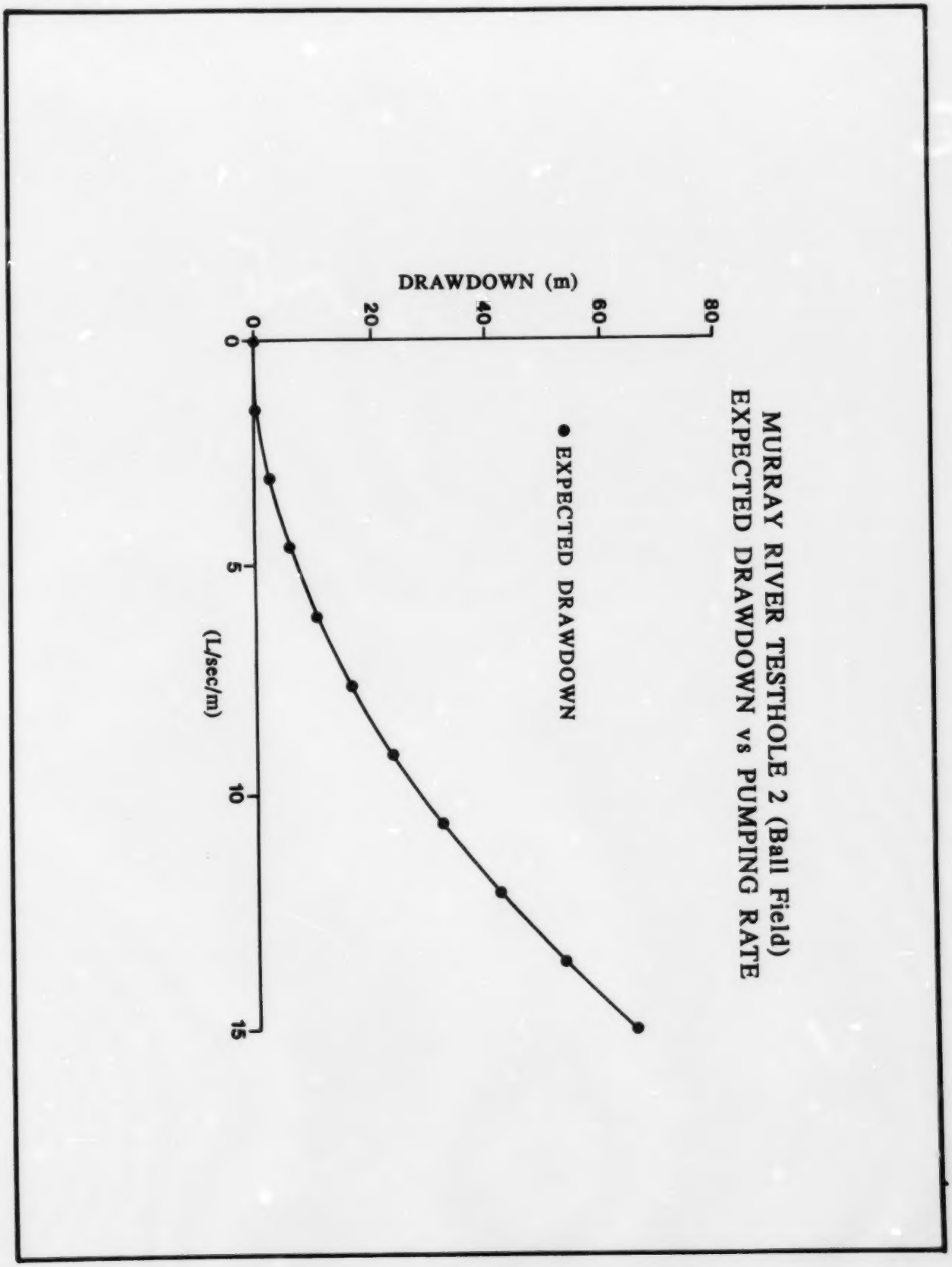
Figure 5 shows the theoretical relationship between pumping rates and drawdown in the well, based on the step drawdown data. It should be noted that this data applies, strictly speaking, only for pumping periods of 1/2 hour; actual drawdown for longer pumping periods are likely to be somewhat greater. In addition any extrapolation beyond of these values beyond the highest pumping rate should be made with caution, as the mathematical function used to calculate these values is only an approximation.

The step drawdown data suggest that the well is capable of yielding approximately 11.4 L/sec, at least for short periods of time, however the drawdown is substantially lower at a rate of 10.5 L/sec, which would lead to more efficient extraction of water from the well.

Test hole MR-1 near the Northumberland Arena was initially intended to be subjected to a 4 stage step drawdown test, using a 3 hp. electric submersible pump, set at a depth of 41 m. Discharge rates were measured by timing the rate at which a container of known volume was filled, and water levels were measured according to the same procedure used for test well MR-2.

Unfortunately, difficulties with the pumping equipment, and lower than expected well yields, precluded conducting more than 2 steps, thus rigorous analysis of the results was not possible. The first step was conducted at a rate of 2.9 L/sec, although a blown fuse on the generator interrupted the test during the first two to three minutes. The resulting drawdown at the end of the first step was 15.49 m, with a specific capacity of 0.18 L/sec/m.

Figure 5


MURRAY RIVER TESTHOLE 2 (Ball Field)
EXPECTED DRAWDOWN vs PUMPING RATE
DRAWDOWN (m)
0
20
40
60
80
0
5
10
15
(L/sec/m)
• EXPECTED DRAWDOWN

During the second step of the test a pumping rate of greater than 4.9 L/sec could not be maintained, even with the valve on the discharge line wide open. Again an electrical problem interrupted pumping in the first few minutes of the test. The resulting drawdown at the end of the second step was 24.12 m, with a specific capacity of 0.20 L/sec/m.

In this case a slight increase in specific capacity is noted with increasing pumping rates, contrary to what one might expect. The most probable explanation for this is that the well was still developing to some extent during the test, resulting in slightly greater well efficiency during the second step.

With only two steps being conducted during this test, the more rigorous analysis applied to test hole MR-1 is not possible, but the results do suggest that at a minimum the well can sustain a pumping rate of 4.9 L/sec but probably not more than 6 or 7 L/sec.

Constant Rate Test:

To further evaluate the aquifer characteristics in the vicinity, a 48 hour constant rate test was conducted with test hole MR-12 being pumped at a rate of 9.8 L/sec, with water level measurements being made in test holes MR-1 and 2. following completion of the test, recovery measurements were made in test hole MR-2 for a period of 3 hours. The pumping arrangements were the same as for the step drawdown test on test well MR-2.

At the end of the 48 hour period, the pumping water level in test well MR-2 was 31.19 m corresponding to a drawdown of 29.66 m. In test hole MR-1 the final water level was 5.73 m for a drawdown of 1.49 m.

The results of the test were analyzed by the curve matching method of Theis, and by the Jacob "straight line" method using both manual and computer fitted techniques, to obtain representative values for aquifer transmissibility and storativity.

Although there is some variability in the Transmissibility values obtained, depending on the method of analysis and the assumptions made, a value between 190 and 240 m^2/day is probably representative of the aquifer in this area. Storativity values from various analyses were in relatively good agreement with an average value of 5.33 x 10-4.

This would indicate that the cone of depression for either of the wells will be relatively shallow, but of considerable areal extent.

4.3 Groundwater Flow Regime

Because of the relatively sparse amount of water well data from the community of Murray River, it is not possible to provide more than a generalized view of the groundwater flow regime. In addition, some of the existing data such as well locations and static water levels is somewhat suspect, further complicating the construction of an accurate picture of the hydrogeological conditions in the area. Figure 6 presents the probable configuration of the groundwater flow regime, based primarily on the topography of the area, and augmented where possible by existing well data.

In general it is expected that groundwater flow is towards the river (ie. to the south in the portion of the community north of the river and to the north in areas south of the river.

The hydraulic gradient would be expected to be somewhat steeper and groundwater flow velocities greater south of the river, because of the steeper topographic gradients found here, providing that aquifer characteristics are generally similar throughout the area. North of the river the topographic gradient varies, but in the central portion of the community averages approximately 2 - 3 %, From the data available, the hydraulic gradient towards the river from the north is approximately 1.5 %. Just east of the community,on the north side of the river, topographic gradients are considerably steeper but no well data exist to predict hydraulic gradients. South of the river the topographic gradient from south to north averages about 4.5 % , and the hydraulic gradient is about 2.4 %.

It is uncertain how profound an influence on groundwater flow regime, some of the more minor pertubations in topography have in the area. For example, well data in the area of the hill just east of Route 4, between the center of the community and the Northumberland Arena, indicate only a minor change in static water levels (as measured from sea level) in spite of the local topographic relief. It is suggested that the effect of these features is likely to be limited to relatively shallow depths, and that at greater depths the main influences on the hydrogeological regime are the river and the two areas of higher ground that broadly define the Murray River Valley.

The delineation of discrete recharge and discharge areas is usually difficult on Prince Edward Island, because of the nature of the underlying aquifers and the relatively gentle topography. With the relatively small volume of reliable data, and the fact that most of the data comes from wells of approximately the same depth, only a hypothetical sketch of the vertical components of the groundwater flow regime can be constructed.

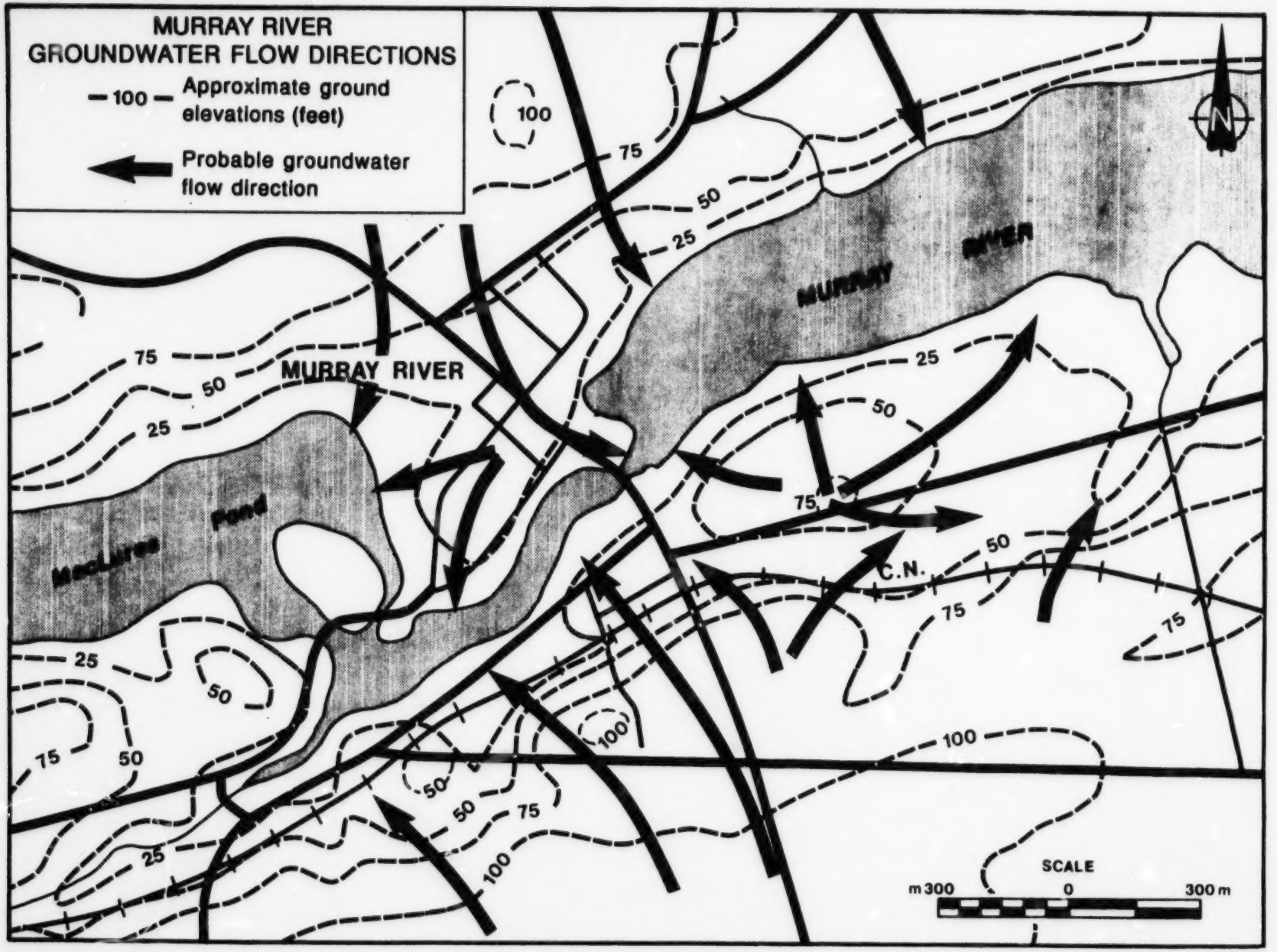

MURRAY RIVER
GROUNDWATER FLOW DIRECTIONS
100
Approximate ground elevations (feet)
Probable groundwater flow direction
MURRAY RIVER
MURRAY RIVER
McClures Pond
C.N.
N
SCALE
m 300
0
300 m

Figure 6

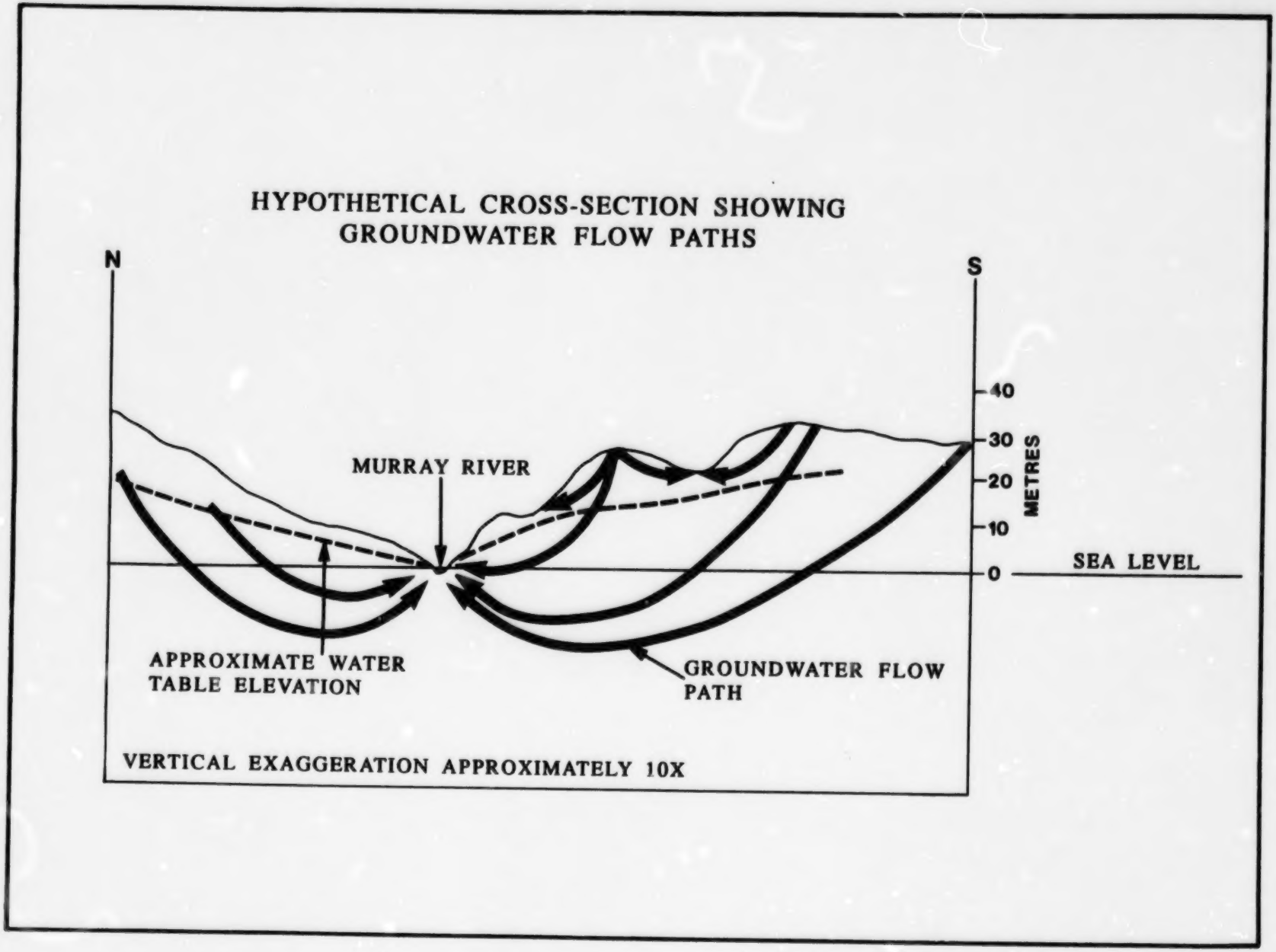

HYPOTHETICAL CROSS-SECTION SHOWING
GROUNDWATER FLOW PATHS
N
S
40
30
20
10
0
METRES
SEA LEVEL
MURRAY RIVER
APPROXIMATE WATER
TABLE ELEVATION
GROUNDWATER FLOW
PATH
VERTICAL EXAGGERATION APPROXIMATELY 10X

Figure 7

The presence of some perennially wet areas , well above the elevation of the river on both the north and south sides of the river, could indicate areas of groundwater discharge, or conversely may only reflect locally poorer drainage characteristics. This latter explanation is somewhat unlikely however, considering the highly permeable nature of the overburden materials throughout the area (dominantly glacio-fluvial sediments and sandy ground moraine.)

On the south side of the river, along the base of the valley wall there are a number of small brooks that appear to be spring fed. In addition, the relatively high static water levels in the 60 m deep test wells, when compared with the nearest domestic wells which are on average about 30 m deep, suggest an upward vertical gradient in this area, possibly indicating an area of groundwater discharge. It should be noted in this case, that the domestic wells are located on a hill with a surface elevation of approximately 10 m higher than the test site, al;though this elevation difference has been taken in to account, the deferent position with respect to shallow local flow systems may account for a significant portion of the apparent upward vertical hydraulic gradient.

Based on the available data and topographic considerations, it is suggested that an appreciable portion of the lower lying areas of the community may be groundwater discharge areas, at least from a regional perspective, receiving recharge from the higher ground on either side of the valley. Smaller and probably shallower flow systems may exist within the valley, with recharge occurring in areas of higher elevation and discharge occurring in lower lying areas.

Figure 7 shows a hypothetical cross - section of the Murray River Valley drawn roughly north - south through the community, showing possible groundwater flow paths. It must be recalled however, that a considerable amount of speculation was involved in the construction of this diagram, which is intended for illustration purposes only. For both this cross section and the plan view of flow regime presented in Figure 6, further reliable well data on static water levels would be required to substantiate, and further refine the true character of the groundwater flow regime in the area.

5.0 Groundwater Quality

Data on groundwater quality for the Murray River area are relatively sparse. The available chemical analyses for groundwater samples from the area indicate that the water is of a calcium bicarbonate type, with moderate hardness values, usually less than 150 mg/l. natural groundwater quality is generally excellent, although locally the occurrence of elevated iron and manganese is reported. Iron and manganese concentrations in the ranges reported constitute an aesthetic problem only and due not pose a health threat. Only rarely have incidences of salt water intrusion been reported.

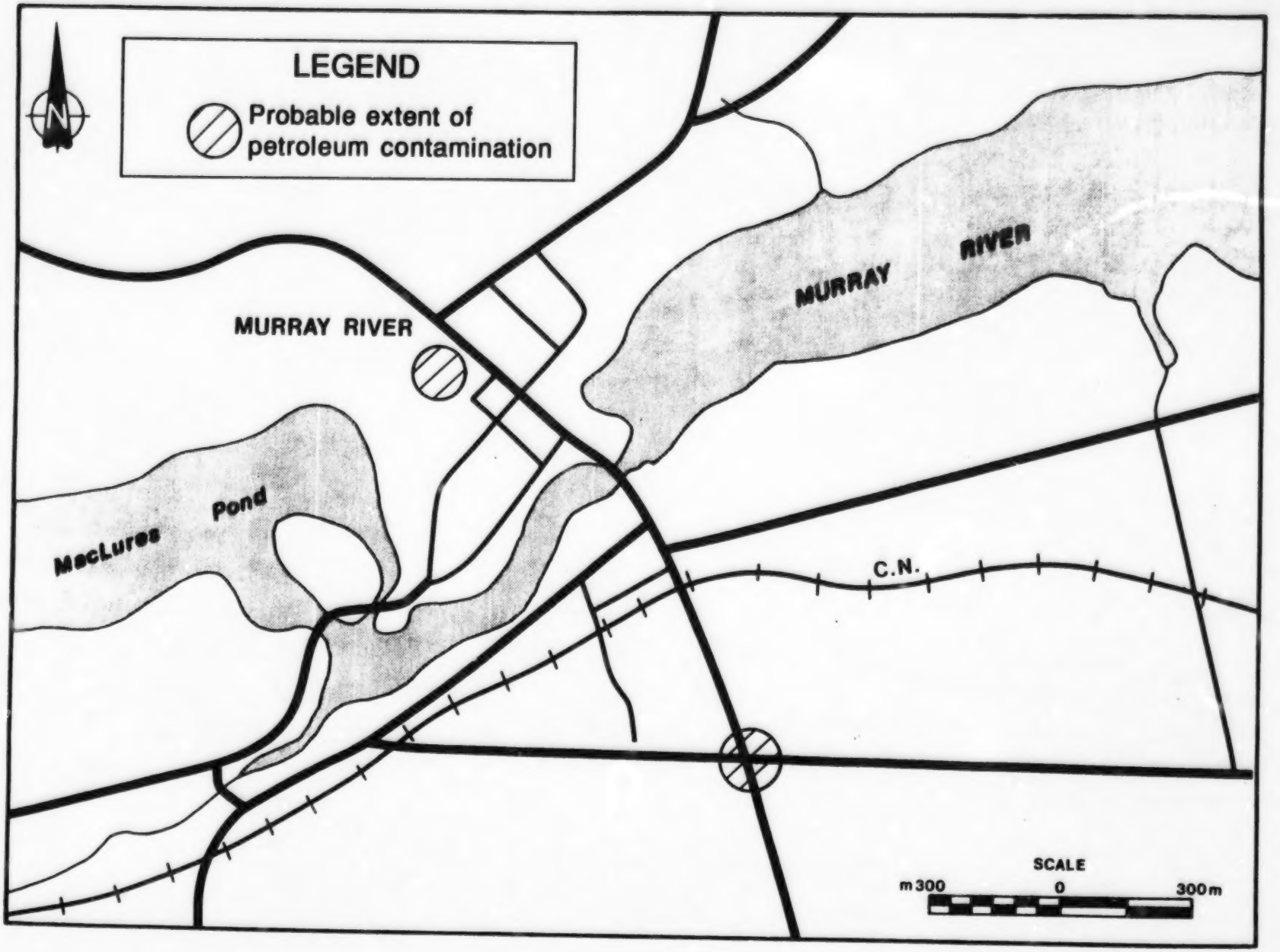

LEGEND
Probable extent of petroleum contamination
N
MURRAY RIVER
MURRAY RIVER
MacLures Pond
C.N.
SCALE
m 300
0
300 m

Figure 8

The occurrence of high iron and manganese concentrations is perhaps somewhat surprising in light of the relatively high hydraulic gradients and transmissibilities which might be expected to lead to relatively rapid groundwater flow in the area. Frequently on P.E.I. elevated iron and manganese levels area found to be correlated with low lying swampy ground in regions of sluggish groundwater flow and chemically reduced groundwater. It is possible that areas with elevated concentrations of these elements are in the discharge portion of longer regional flow systems, which drain some of the flat lying, swampy ground that occurs on the higher ground on either side of the Murray River Valley.

In spite of the fact that the Murray River is relatively saline within the reaches where the community is situated, the available data shows little evidence of salt water intrusion, and only in one instance a well on the north shore of the river is reported to have yielded salty water. It is probable that with the relatively steep hydraulic gradients in the region, (particularly on the south side of the river), and the distance inland from any sizable body of saltwater, that any salt water/fresh water interface that may exist is relatively steep and close to the river. Therefore it is not expected that saltwater intrusion is likely to be a serious constraint on the development of water supplies in the Murray River area.

There have been relatively few man-made water quality problems the community except for a few spills of petroleum products. These consist primarily of a number of small fuel oil and gasoline spills that have only had local effect. The areas presently affected by these spills are shown on Figure 8. It is important to note though, that the most common threat to groundwater quality on Prince Edward Island is contamination by petroleum products from leaking underground storage tanks. The community has already been the site of a few of these incidents, and it is only realistic to expect that other spills will occur in the future. Therefore groundwater in the immediate vicinity around service stations or other locations where significant quantities of petroleum products are stored is probably at some risk of contamination. It is worth mentioning also that while large underground petroleum storage tanks perhaps pose a greater risk to groundwater resources when taken individually, because of their numbers, domestic home heating oil tanks have statistically account for a significant portion of contamination events.

6. Planning Considerations

6.1 Availability of Groundwater

The community of Murray River is fortunate in having abundant groundwater resources, and there is expected that the continued reliance on on-site water supplies will be adequate to meet the water volume requirements in the foreseeable future.

With a population of around 450 people it is likely that the average daily flow requirements for the community is in the range of 122 m^3/day roughly 1.5 L/sec. Peak flow demand is likely to be about three times this figure or around 4.5 L/sec. In the event that the community elected to change from on - site to central water supply servicing, the test drilling conducted to date indicates that these volume requirements would be easily met with one or two production wells.

The two test wells constructed near the Northumberland Arena are estimated of providing a combined total of 13.6 L/sec (1173 m^3/day), far in excess of the expected water demands in the foreseeable future. While no test drilling was conducted elsewhere in the community there is no indication that significant sources of water supply could not be developed in other areas as well, considering the relatively modest requirements of the community, especially if the sites are chosen in relatively low lying areas.

When considering any area for the development a water supply which will involve substantial groundwater withdrawals, it is important to ensure that the area under consideration can support the required level of pumping with out creating adverse effects on other water users. This includes the possible effects on other wells in the vicinity as well as any impact on the contribution of groundwater to surface water flows.

In Prince Edward Island surface water divides and groundwater divides are generally thought to coincide (Francis, 1989), allowing the delineation of hydrogeological regimes into systems based on surface watershed extent. The level of groundwater withdrawal possible without adverse impacts to other water users is a function of the areal extent of the watershed contributing water to the well field, and can be based on the amount of available recharge. Figure 9 outlines the boundaries of the Murray River watershed in which the Community of Murray River is located. The shaded area of the watershed represents the area which would be expected to contribute groundwater to a well field located in the Murray River area (approximately 58 km^2).

For the purposes of this report it can be assumed that up to 50% of the available recharge may be safely withdrawn without adversely affecting stream flows in the area. Typical recharge rates on the Island are in the range of 35 % of annual precipitation which averages 1100 mm. Using these assumptions the amount of groundwater potentially available for extraction would be on the order of 350 L/sec, or over 30,000 m^3/day, far in excess of the communities requirements in the foreseeable future.

It is likely that water quality concerns would play a greater role in the selection of potential sites. While sites too close to the river should be avoided due to the risk of salt water intrusion, the steep hydraulic gradients toward the river (especially on the south side) would probably limited the extent of salt water intrusion to narrow zone extending a hundred meters or so from the river shore, at least at the pumping rates considered here.

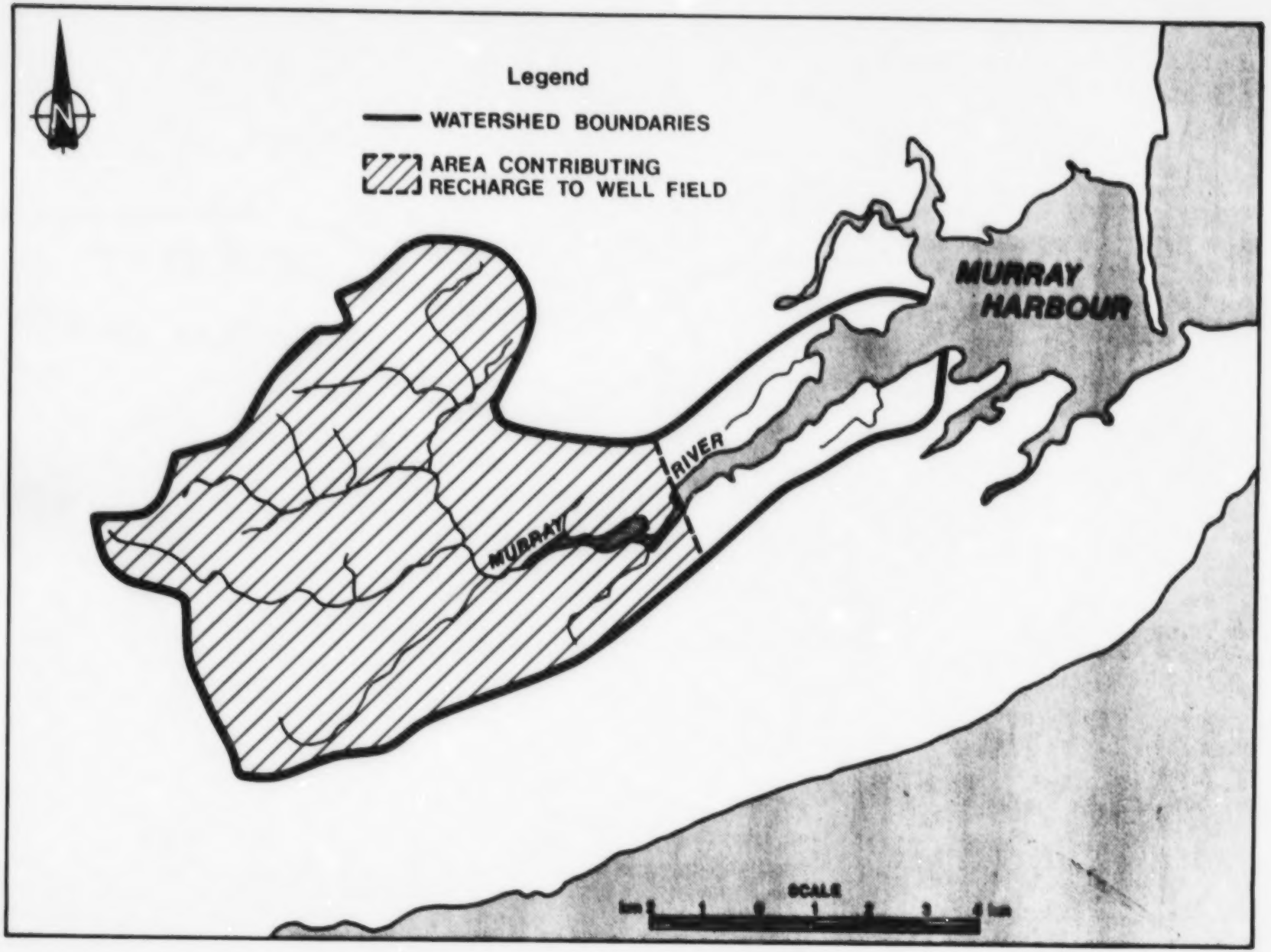

Legend
WATERSHED BOUNDARIES
AREA CONTRIBUTING
RECHARGE TO WELL FIELD
MURRAY
HARBOUR
RIVER
MURRAY
SCALE
km
km

Figure 9

Historical problems with high iron and manganese concentrations in the portion of the community north of the river make this area of the community less attractive for the source of a suitable water supply.

On the south side of the river areas with only a thin cover of overburden would be relatively susceptible to contamination borne by surface and near surface water. As an example, one location which was examined as a potential test drilling site near the former railroad station was rejected in part because it was felt that bedrock would be encountered with in a few feet of the ground surface. In a case such as this, it would be difficult to prevent surface or near surface water from entering the well, even if the well casing was properly sealed in the ground. If surface water did gain access to the well, the well would then potentially act as a conduit, allowing spread of this water to larger portions of the aquifer. It is possible however, that an upward vertical hydraulic gradient (if present) would prevent significant infiltration of this water into the aquifer, at least in areas outside the immediate area of influence of the wells.

The site chosen for test drilling appears to be well suited as the location of a water supply in most respects, with the absence of any development activity which is likely to have an adverse effect on a water supply, an ample quantity of good quality water, and a location which would make the implementation of some form of groundwater protection measures relatively straight forward. The main drawbacks of this location are the distance from the center of greatest water demand, and the relatively low elevation of the site which might be expected to result in higher pumping costs than a location on higher ground.

6.2 Groundwater protection strategies

The importance of groundwater resources to the health and welfare of the Island communities is well recognized. To a lesser extent, the importance of implementing sound, far sighted strategies aimed at protecting this valuable resource is also appreciated. The following discussion attempts to provide some focus to the issue, by presenting some possible approaches to the development of a comprehensive groundwater protection strategy.

The issue of groundwater protection can be separated into two components: specific recommendations for the protection of central water supply wells or well fields; and general considerations pertinent to the establishment and operation of on - site water supplies and protection and preservation of groundwater resources in general.

It is worth commenting at this point that even if a community has no intention of developing a central water supply in the foreseeable future (and indeed, such a consideration may not be appropriate to the development plans of a community), it is highly desirable to consider this possibility, and to be aware of the requirements and constraints involved in the development of a

central water supply. This exercise ideally would involve the identification suitable locations for the development of such a supply and appropriate strategies to preserve the resource for future use.

Well field protection

Unlike the processes that lead to the contamination of surface water bodies, the degradation of groundwater resources is not subject to direct observation, and consequently more difficult to predict, correct and avoid. Once contaminants have been introduced into a groundwater system, their migration and fate is governed by a complex series of reactions and processes which depend on a number of parameters which may be only poorly documented . Consequently the prediction of the consequences of the introduction of contaminants into a groundwater receiver in the vicinity of wells supplying a water supply system requires a number of approximations and assumptions of varying validity.

A number of approaches have been developed to provide varying degrees of protection to the wells supplying central water supply systems. In general, the object of these strategies is to designate a given area around the well or well field for which activities which have the potential to impact on the integrity of the water supply are regulated or prohibited.

"The major parameters in developing groundwater protection strategies for municipal water wells are legal, socioeconomic and hydrogeological" (Allan Gregory, 1988), In this report suggested protective strategies are based primarily on hydrogeological parameters. It is recognized that the modification of these strategies in light of socioeconomic factors is an inevitable and desirable aspect of the development of appropriate strategies for individual communities.

Typical methods by which the size of a protective zone are:

1) Zone or Radius of influence - a zone based on the drawdown characteristics of the well and its effective radius of influence.

2) Delay time - the distance potential contaminants could travel towards a well in a given time period under the prevailing hydrogeological conditions.

3) Recharge area - the areal extent of the aquifer that contributes water to the well under the natural flow regime alone or in combination with the effects of pumping.

These three methods have the appeal that they can be based on the actual characteristics of the aquifer, and may thus be justified to some extent on the basis of their scientific foundations. It should be noted at the outset however, that rarely are the aquifer characteristics sufficiently well known that the suggested protection zones provide an absolute guarantee of protection.

Nonetheless, these approaches can help in developing rational water management policies, which can be refined and improved as additional information or insight into actual field conditions are accumulated.

Each of the approaches described above has strengths and weaknesses, and it is perhaps advisable to develop well field protection strategies which incorporate the most appropriate aspects of each approach. It is recognized that the community may have no need of a central water supply in the foreseeable future, yet it is instructive to gain an appreciation of what might be involved in the protection of a central water supply under the prevailing hydrogeologic conditions. For the purposes of illustration, the extent of several well field protection zones has been calculated for the two test wells drilled as part of this study.

Because it is not known what the water demand might be at such a time as this resource might be developed, it is assumed for the purpose of these calculations that the level of groundwater withdrawals is at the full capacity of the two wells. While this level of groundwater extraction might be considerably in excess of the communities needs, it might require only a small amount of industrial development to make these figures realistic. Furthermore, because of the hydraulic properties of the aquifer,the size of the protection zones as they would apply to a well field supplying only the community's current demands, while somewhat smaller, are not much different from those presented here. The extent of these theoretical well field protection zones is shown on Figure 10.

Radius of Influence:

When water is pumped from a well, the water table or hydraulic head is depressed in the surrounding aquifer, creating a "cone of depression" around the well. The areal extent of this cone shaped depression is frequently referred to as the radius of influence of the well and represents the area in which the effects of pumping are superimposed on the natural hydraulic regime. Within this area it is recommended that no residential , commercial or industrial development take place, and that restrictions be placed on agricultural activities. The area would however be suitable for some types of recreational uses however.

From a theoretical standpoint, this radius of influence may be of infinite extent, but from a practical perspective a finite area can be identified beyond which the influence of pumping is either nonexistent or negligible. In this report, the radius of influence will be considered the distance at which the hydraulic gradient induced by pumping is less than or equal to the natural hydraulic gradient, or at some natural hydrogeological boundary.

In addition, certain other assumptions must be made. First it is assumed that the relevant aquifer parameters are reasonably represented by the pump test data. Secondly it is assumed that pumping continues on a continuous basis for a period of 180 days with out any recharge to the aquifer.

Based on these assumptions it is predicted that the radius of influence for test hole MR-1 pumping at a rate of 4.8 L/sec would be approximately 75 m, and for test hole MR-2 pumping at a rate of 9.8 L/sec the radius of influence would be approximately 150 m.

60 Day Delay Time Zone - an area enclosed by a line representing the distance from which potential contaminants are expected to migrate towards a well in a given period of time (60 days in this case) under pumping conditions. The choice of a 60 day delay time is based on two considerations. First, 60 days is the maximum period of time most pathogenic organisms are believed to survive in the groundwater, thus providing a measure of protection form these sources of contamination. Secondly, the 60 day zone provides a reasonable amount of time to implement remedial measures in the event that some incident of contamination occurs near the boundary of the zone.

Within this area it is recommended that on - site sewage disposal is prohibited, and the storage, or handling of hazardous materials including petroleum products be prohibited. In addition any other development proposals or activities should be subjected to an environmental impact assessment, at least in regard to their possible impact on groundwater resources.

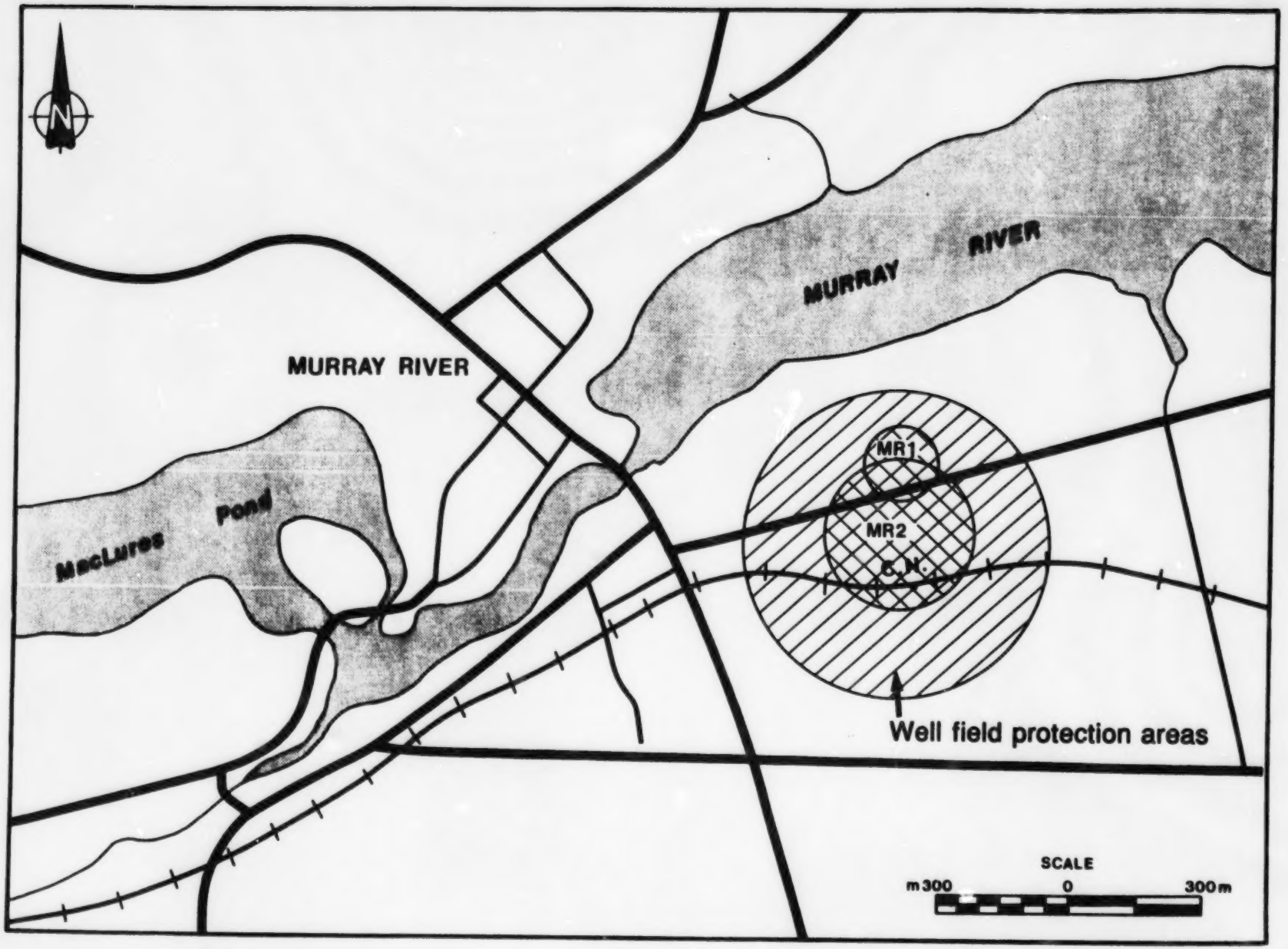

N
MURRAY RIVER
MURRAY RIVER
MacLures Pond
MR1
MR2
C.N.
Well field protection areas
SCALE
m300
0
300m

Figure 10

For test well MR-1 and MR-2 the 60 day delay time zones will overlap and would extend in an uphill direction approximately 335 m to the top of the hill between the well sites and the centre of the community. In a down hill direction, the zones would extend 75 m and 150 m respectively for wells MR-1 and MR-2.

Recharge area The recharge area represents the area in which groundwater is expected to flow towards the wells under the influence of pumping, or under the existing natural gradient. Within this area, major development proposals or proposed land use changes should be subjected to an environmental impact assessment.

In the case of the two well sites identified in this study, the recharge area will be very similar to the 60 day delay time zone, except that it will extend further to the south to the topographic high situated near Route 18 to Murray Harbour.

7. Conclusions and Recommendations

The results of the investigations undertaken as a part of this study indicate that the community of Murray River is fortunate in having an abundant supply of generally good quality groundwater. Where water quality has been of concern, it is primarily because of naturally occurring high iron or manganese concentrations, or locally instances of saltwater intrusion. Some man - made contamination of the groundwater has occurred in the past, but has been primarily of localized extent.

While development stresses on the groundwater resources are probably not great, there are a number of areas within the community where the aquifer is relatively vulnerable to contamination, particularly in some of the southern part of the community where soils are thin and of high permeability. In regions of this nature particular care should be taken that well are properly constructed and old wells properly abandoned to prevent contamination of the well and adjacent portions of the aquifer by poorer quality surface water.

Both existing well data and test drilling indicates that adequate quantities of water are generally easy to obtain throughout most of the community, and that on - site sources of water supply are likely to continue to meet community needs for the foreseeable future. It is more likely that the constraints on the development or maintenance of water supplies in the area will come from water quality concerns, either manmade or otherwise. It would be prudent for the community to identify an area or areas within the community which could be protected for future water supply development at some time in the future, should the need ever arise. Test drilling at the site investigated as a part of this program has identified an ample supply of good quality groundwater. It is likely that other areas within the community or on close proximity might

have similar potential for water supply development. The critical element in selecting suitable sites for groundwater development are likely to be water quality considerations, as well as identifiyin. a land base upon which appropriate well field protective measures may be imposed.

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APPENDIX I

WATER WELL DATA

MURRAY RIVER

WATER WELL DATA

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Strickland, Vance	710818	529300	5066100	58	80	25	48	17		0–40 Coarse sandstone 40–58 Rock	
MacLeod, David	830801	529800	5066200	100	80	25	81	10	8	0–27 Till 27–100 Sandstone and claystone	
Spencer, Allan	740801	529800	5066300	81	80	35	44	8	15	0–42 Sand, some clay 42–81 Sandstone	46 80 74 77
Graham, Rauldon	521827	529800	5066800	85	80	80	43	7	8	0–25 Till and claystone 25–90 Sandstone, some claystone	80 83 83 86
Singleton, Parley	710815	529800	5064800	75	80	40	32	15			
Spencer, Allan	781008	525800	5066800	135	80	55	110	8	60	0–40 Till 40–135 Sandstone	
Miller, Rick	800422	529800	5066800	108	85	80	80	8	10	0–80 Mud 80–108 Sandstone, some claystone	80 108
Miller, James	790714	525800	5066700	80	80	30	62	8	8	0–80 Sand 80–80 Sandstone	
Pomey, Roy D.	800809	530180	5064700	80	100	40	33	10	8	0–33 Claystone 33–90 Sandstone, some claystone	40 80
Johnston, Orwell	790822	530200	5066300	105	25	15	39	6	8	0–37 Till 37–105 Sandstone	
Stewart, William	800704	530400	5065300	85	75	54	30	7	10	0–36 Till 36–85 Sandstone	54 85
Miller, Rick	850815	530400	5066100	70	23	70	54	7	10	0–30 Till 30–70 Sandstone	64 70
Bell, Alan	850121	530600	5064500	90	75	80	44	7	9	0–40 Till 40–90 Sandstone	80 80
Horne, Janis	790803	530600	5066400	90	75	54	53	6	8	0–20 Till 20–90 Sandstone	54 90
Campbell, Brenton	710909	530600	5067300	58	75	31	32	15			
Williams, Charlie	850815	530800	5064600	85	75	27	42	8	10	0–27 Till 27–85 Sandstone	42 85
Dixon, David	850803	530800	5066400	100	80	46	81	8	15	0–46 Till	46 100

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (lgpm)	Time (min)	Geology	Aquifers (Water Occurrences)
										45–100 Sandstone	
Livingstone, George	730725	550400	5555500	70	78	42	35	6	60	0-5 Clay	
										5-70 Sandstone	
MacDonald, Lodo	711010	530500	5556700	65	85	60	45	10		0-15 Sand	
										15-65 Sandstone	
MacLeod, Ralph	611504	551000	5555000	80	65	30	42	5	7	0-4 Till	60 63 71 74
										4-80 Sandstone, some claystone	
Martin, Bruce	700718	551100	5556500	60	85		54	6	7	0-22 Till	34 56
										22-60 Sandstone	
		Averages		66		41	46	6			

APPENDIX II

WATER QUALITY DATA

APPENDIX II
Water Quality Analyses
MURRAY RIVER

Name&Date		Easting/Northing	Parameters Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	pH	Fe (T)	Fe (D)	Mn	Cd	Cu	Cr	Ni	Pb	Zn
Boyd Allen	830223	529700/5086310	15.7	6.89	16.9	1.79		98	18	< 1	0.04	0.3	7.9	< 0.1	< 0.1	0.20		0.03			< 0.1	0.24
V. Belleville	861112	530660/5086300	21.1	10.76	22.1	2.61	89.4	73	18		0.07	3.6	7.3	< 0.1	< 0.1	< 0.02		0.19			< 0.1	1.45
Edith Davey	870803	530250/5084700	24.3	14.41	10.7	2.23	153.6	100	42		0.22	< 0.2	6.8	18.0	< 0.1	9.00		0.04			< 0.1	11.10
Edith Davey	870817	530250/5084700	29.4	15.03	9.4	1.84	136.5	114	20		0.12	0.3	7.4	0.4	< 0.1	0.53		< 0.02			< 0.1	0.07
Cecil Giddings	830223	529800/5086400	21.8	9.33	15.0	1.67		130	17	< 1	0.06	< 0.2	7.9	< 0.1	< 0.1	0.19		0.05			< 0.1	0.87
Frank Gosbee	870325	529900/5086300	20.0	11.27	6.5	3.70	96.6	114	10		0.12	2.0	7.4	< 0.1	< 0.1	0.04		< 0.02			< 0.1	< 0.02
Glen Gosbee	821104	532800/5084800	27.0	10.28	7.4	1.89		96	10	5	0.09	0.3	8.0	0.3	< 0.1	0.03	< 0.05	0.07	< 0.02	< 0.05	< 0.1	0.80
Dan Horton	870908	530030/5084700	36.2	22.34	7.9	1.74	189.0	168	40		0.07	0.2	7.3	0.3	< 0.1	0.52		< 0.02			< 0.1	0.35
Barry Hume	830223	529780/5086480	27.3	12.41	10.1	4.12		194	23	< 1	0.06	0.4	8.0	< 0.1	< 0.1	0.96		0.04			< 0.1	0.19
Gladys MacDonald	830915	529800/5084800	31.7	12.98	3.5	1.80	133.0	130	7	< 1	0.10	0.6	7.9	< 0.1	< 0.1	0.06		0.03			< 0.1	0.18
Lexie MacDonald	830223	529900/5086400	20.6	8.67	14.2	1.94		105	14	< 1	0.05	0.5	7.7	< 0.1	< 0.1	0.10		0.03			< 0.1	0.09
David MacLeod	830223	529700/5086400	19.4	8.63	14.9	2.51		114	17	3	1.00	< 0.2	7.8	0.9	< 0.1	0.36		< 0.02			< 0.1	0.06
David MacLeod	840314	529700/5086400	18.3	8.34	6.7	2.14	83.2	104	9		0.10	< 0.2	7.0	0.8	< 0.1	0.25		0.02			< 0.1	0.04
Sam MacLeod	860810	530060/5086300	22.7	8.79	4.5	1.22	86.7	107	10		0.09	0.5	7.7	< 0.1	< 0.1	0.21		0.09			< 0.1	0.34
Peter Milburn	870805	529950/5086450	27.3	15.49	13.6	3.26	134.3	124	30		0.06	< 0.2	7.4	1.1	< 0.1	1.18		< 0.02			< 0.1	< 0.02
Jamie Miller	870415		33.7	17.50	20.5	2.84	156.9	171	60		0.03	3.3	7.5	0.3	< 0.1	0.13		0.08			< 0.1	0.17
Ricky Miller	850904	530500/5086050	20.5	12.30	73.0	3.42	105.4	73	130		0.15	< 0.2	7.0	1.5	1.1	0.32		0.06			< 0.1	0.65
Ricky Miller	851017	530500/5086050	13.6	8.53	16.2	2.35	70.2	82	11		0.02	0.5	7.8	0.2	< 0.1	0.11		0.16			< 0.1	0.48
Joanne Murphy	870805	530650/5086350	17.4	9.45	5.3	1.41	88.6	70	10		0.06	0.7	6.8	5.4	< 0.1	2.61		0.04			< 0.1	0.86
Pentecostal (C)	871209	530000/5086600	20.5	21.33	29.7	10.00	139.3	140	33		0.21	2.0	7.6	< 0.1	< 0.1	< 0.02		0.11			< 0.1	0.07
Pentecostal (H)	871209	530000/5086600	43.3	13.84	18.8	12.20	172.6	182	21		0.40	0.6	7.0	61.0	0.6	2.84		0.22			< 0.1	0.81
Sage Robbins	830223	529780/5086180	20.3	7.10	16.3	2.36		112	18	3	0.04	< 0.2	7.8	0.2	< 0.1	0.27		0.06			< 0.1	0.68
Edward Shipley	801127	529900/5086400					167.0		28			7.3	7.5	0.1								
Edward Shipley	830223	529900/5086400	19.5	7.73	17.6	2.33		112	22	2	0.06	0.6	8.1	< 0.1	< 0.1	0.15		0.14			< 0.1	0.39
Alexis Shumate	830223	529900/5086400	21.4	11.42	31.6	2.85		156	24	5	0.06	< 0.2	8.1	< 0.1	< 0.1	0.12		0.03			< 0.1	0.30
Allan Spencer	761102	529900/5086500	37.0	19.25	10.0	2.60	179.0	139	30	< 5	0.06	< 0.2	8.0	0.1	< 0.1	0.02		< 0.02			< 0.1	0.07
Fantasyland P.P.	810622	533400/5086500	35.0	10.00	7.0	1.65	118.0	83	8	8	0.10	< 0.2	7.4	0.1	< 0.1	< 0.02		0.15			< 0.1	0.44
Fantasyland P.P.	850731	533400/5086500	22.2	9.23	5.7	1.25	93.8	101	16		0.14	0.5	7.9	< 0.1	< 0.1	< 0.02		0.05			< 0.1	0.10
Sr. Citizens	810722	529800/5085990	32.0	14.00	8.0	2.00	137.0	121	17	7	0.12	1.7	7.8	< 0.1	< 0.1	< 0.02		0.50			< 0.1	0.40
Sr Citizen (C)	841030	529800/5085990	34.9	16.01	7.1	2.06	154.6	136	16		0.18	1.6	7.7	< 0.1	< 0.1	< 0.02		0.08			< 0.1	0.87
Sr Citizen (H)	841030	529800/5085990	31.7	15.88	7.2	2.37	146.1	136	16		0.16	2.7	7.8	< 0.1	< 0.1	< 0.02		0.39			< 0.1	0.90
Sr. Citizens	850227	529800/5085990	29.6	15.41	6.9	2.02	136.0	133	17		0.20	1.6	7.8	< 0.1	< 0.1	< 0.02		0.08			< 0.1	0.29
Sr. Citizens	860127	529800/5085990	25.7	14.55	8.2	2.07	124.3	101	22		0.19	2.4	8.0	< 0.1	< 0.1	< 0.02		0.04			< 0.1	0.05